Labs21:
Improving the Performance of Laboratories

September 11, 2006 Dale Sartor, P.E.

Lawrence Berkeley National Laboratory

Energy Use in Laboratories

- **Laboratories are energy intensive.**
  - On a square foot basis, labs often consume four to six times as much energy as a typical office building
  - Clean rooms and data centers are up to one hundred times more energy intensive
- **Most existing labs can reduce energy use by 30%-50% with existing technology.**
- **Laboratories are experiencing significant growth.**
- **Energy cost savings possible from U.S. labs may be as much as $1 billion to $2 billion annually.**

What is Labs21?

- **A joint EPA/DOE partnership program to improve the environmental performance of U.S. laboratories including:**
  - Minimize overall environmental impacts
  - Protect occupant safety
  - Optimize whole building efficiency on a lifecycle basis
- **A growing network of 3,500+ laboratory designers, engineers, facility/energy managers, health and safety personnel, and others.**

Labs21 Program Components

1. **Partnership Program**
   – Draws together lab owners and designers committed to implementing high performance lab design.
2. **Training Program**
   – Includes annual technical conference, training workshops, and other peer-to-peer opportunities.
3. **Best Practices and Tool Kit**
   – An Internet-accessible compendium of case studies and other information on lab design and operation, building on the *Design Guide for Energy Efficient Research Laboratories* developed by Lawrence Berkeley National Laboratory, and more...

Component #1: Partnership Program

- **EPA and DOE partner with lab owners.**
- **Partners:**
  - Commit to a project
  - Assess the opportunities for improvements
  - Set voluntary goals
  - Measure and report progress
  - Share lessons learned

Benefits of Partnership

- **Technical Assistance**
  - Participation in sustainable design charrettes
  - Advice on specific technical issues (e.g. heat recovery, fume hoods)
  - Help using Labs21 toolkit
- **Networking**
  - share results with peers
- **National recognition**

Labs21 Partners

Private Sector Partners

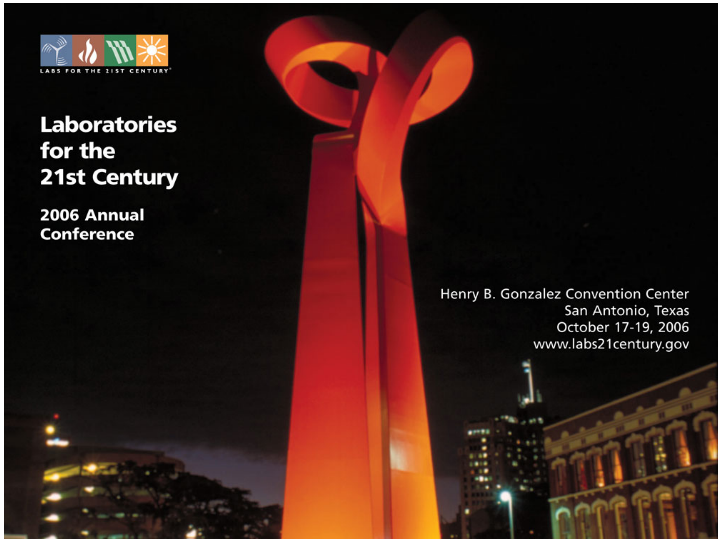
- Bristol-Myers Squibb
- Carnegie Mellon University
- Duke University
- Genzyme
- Harvard University
- New York City Public School Authority
- Northern Arizona University
- Pfizer
- Raytheon
- Sonoma State University
- University of California – Merced
- University of Hawaii
- University of North Carolina – Asheville
- Wyeth-Ayerst Pharmaceuticals

Labs21 Federal Partners

- Lawrence Berkeley National Laboratory
- National Aeronautics & Space Administration
- National Oceanic & Atmospheric Administration
- National Renewable Energy Laboratory
- National Science Foundation
- Sandia National Laboratories
- U.S. Department of Agriculture
- U.S. Environmental Protection Agency

Component #2: Training

- **Annual conference**
- **One day introductory course**
- **Advanced course modules**
  - LEED for Labs
  - Lab ventilation
- **Phone forums on specific topics**
- **Video with case studies**
- **Student design competition**
- **Partnership with UC/CSU/IOU’s**



October 17-19, 2006

Henry B. Gonzalez Convention Center

San Antonio, TX

Labs21 Training and TA is focused on unique challenges and opportunities in Labs

- VAV fumehoods
- Low flow fumehoods
- Energy recovery
- Minimizing reheat
- Low pressure drop design
- Multi-stack exhaust
- Fume hood and laboratory Commissioning
- Indoor air flow modeling
- Optimizing air change rates
- Effluent dispersion
- Plug loads and rightsizing
- Lab equipment efficiency
- Daylighting in labs
- Effective electrical lighting design
- Flexible servicing configurations
- Green materials for labs

Component #3: Toolkit

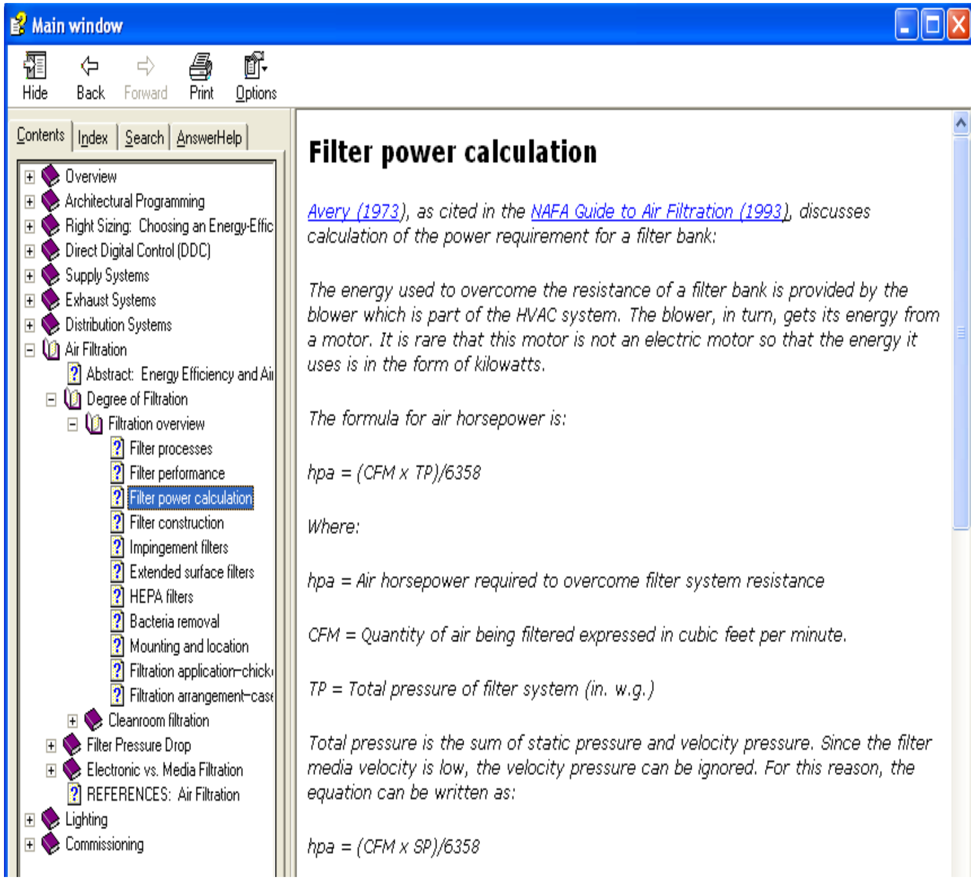
- ***For an overview***
  - Intro to Low-Energy Design
  - Video
- ***Core information resources***
  - Design Guide
  - Case Studies
  - Energy Benchmarking
  - Best Practice Guides
- ***Design process tools***
  - Env. Performance Criteria
  - Design Intent Tool
  - Labs21 Process Manual

www.labs21century.gov/toolkit

Core information resources

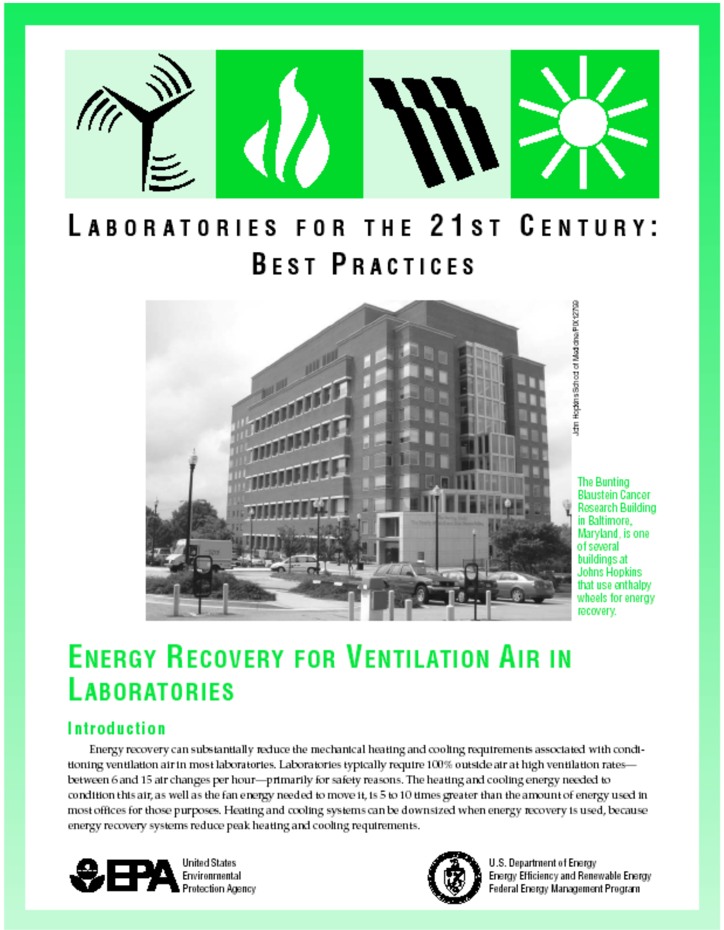
Lab Design Guide

- **A detailed reference on high-performance, low-energy lab design and operation**
- **4-level hierarchy – from general to specific**
- **Searchable**
- **Available on web and CD**



Best Practice Guides

- **Describes how to implement a strategy, with implementation examples**
- **Completed guides:**
  - Combined Heat and Power
  - Daylighting in Laboratories
  - Energy Recovery
  - Low-pressure drop design
  - Modeling Exhaust Dispersion
  - Water Efficiency
  - Minimizing Reheat
  - Right-sizing
- **Several in development**
  - Labs21 seeking contributing authors


LABORATORIES FOR THE 21ST CENTURY:
BEST PRACTICES

John Hopkins School of Medicine/PIX12750

The Bunting Blaustein Cancer Research Building in Baltimore, Maryland, is one of several buildings at Johns Hopkins that use enthalpy wheels for energy recovery.

ENERGY RECOVERY FOR VENTILATION AIR IN LABORATORIES

Introduction

Energy recovery can substantially reduce the mechanical heating and cooling requirements associated with conditioning ventilation air in most laboratories. Laboratories typically require 100% outside air at high ventilation rates—between 6 and 15 air changes per hour—primarily for safety reasons. The heating and cooling energy needed to condition this air, as well as the fan energy needed to move it, is 5 to 10 times greater than the amount of energy used in most offices for those purposes. Heating and cooling systems can be downsized when energy recovery is used, because energy recovery systems reduce peak heating and cooling requirements.

EPA United States Environmental Protection Agency

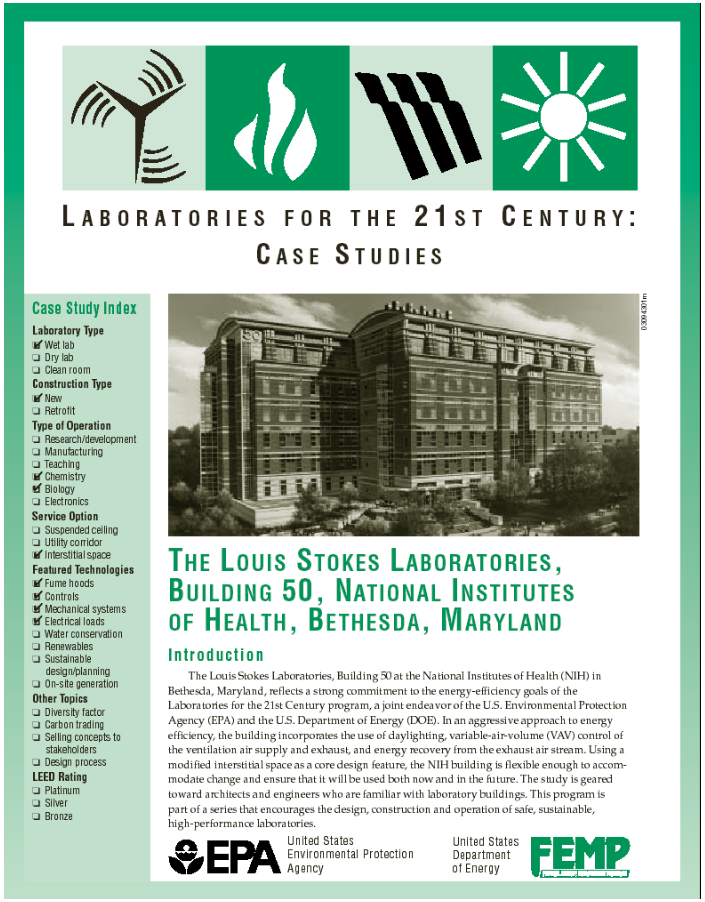
U.S. Department of Energy
Energy Efficiency and Renewable Energy
Federal Energy Management Program

Core information resources

Case Studies

- Bren Hall, UCSB
- Fred Hutchinson Cancer Research Center
- Georgia Public Health Laboratory
- Haverford College Natural Science Center
- National Institutes of Health Building 50
- Sandia National Laboratories PETL
- Nidus Center
- Pharmacia Building Q
- U.S. EPA National Vehicle and Fuel Emissions Lab
- Whitehead Biomedical Research Center, Emory University

All case studies have whole-building and system level energy use data



LABORATORIES FOR THE 21ST CENTURY:
CASE STUDIES

Case Study Index

Laboratory Type
- ☑ Wet lab
- ☐ Dry lab
- ☐ Clean room

Construction Type
- ☑ New
- ☐ Retrofit

Type of Operation
- ☐ Research/development
- ☐ Manufacturing
- ☐ Teaching
- ☑ Chemistry
- ☑ Biology
- ☐ Electronics

Service Option
- ☐ Suspended ceiling
- ☐ Utility corridor
- ☑ Interstitial space

Featured Technologies
- ☑ Fume hoods
- ☑ Controls
- ☑ Mechanical systems
- ☑ Electrical loads
- ☐ Water conservation
- ☐ Renewables
- ☐ Sustainable design/planning
- ☐ On-site generation

Other Topics
- ☐ Diversity factor
- ☐ Carbon trading
- ☐ Selling concepts to stakeholders
- ☐ Design process

LEED Rating
- ☐ Platinum
- ☐ Silver
- ☐ Bronze

03094301m

THE LOUIS STOKES LABORATORIES, BUILDING 50, NATIONAL INSTITUTES OF HEALTH, BETHESDA, MARYLAND

Introduction

The Louis Stokes Laboratories, Building 50 at the National Institutes of Health (NIH) in Bethesda, Maryland, reflects a strong commitment to the energy-efficiency goals of the Laboratories for the 21st Century program, a joint endeavor of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). In an aggressive approach to energy efficiency, the building incorporates the use of daylighting, variable-air-volume (VAV) control of the ventilation air supply and exhaust, and energy recovery from the exhaust air stream. Using a modified interstitial space as a core design feature, the NIH building is flexible enough to accommodate change and ensure that it will be used both now and in the future. The study is geared toward architects and engineers who are familiar with laboratory buildings. This program is part of a series that encourages the design, construction and operation of safe, sustainable, high-performance laboratories.

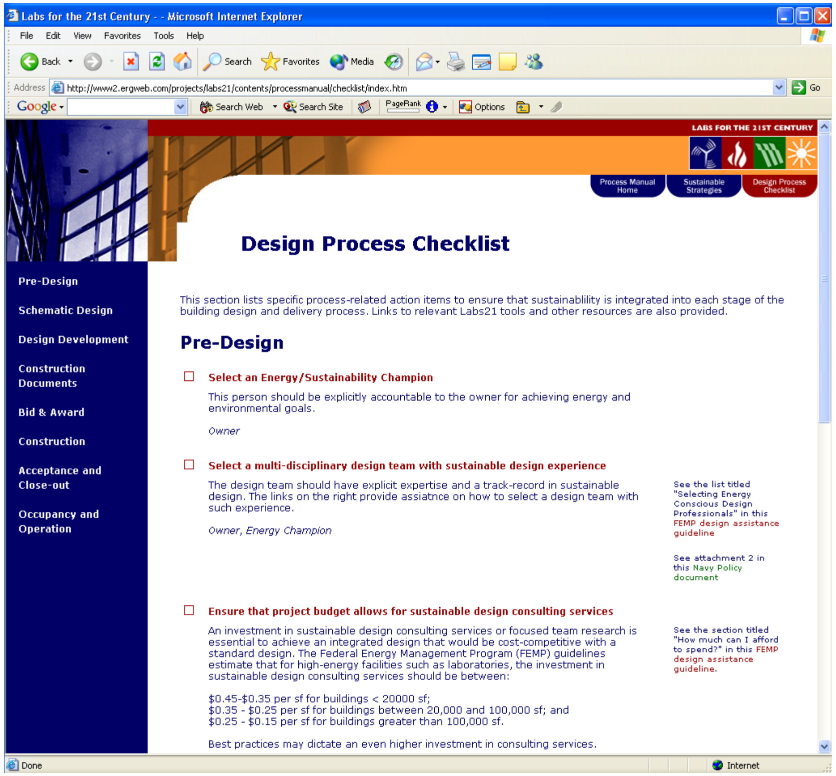
EPA United States Environmental Protection Agency

United States Department of Energy FEMP

Design process tools

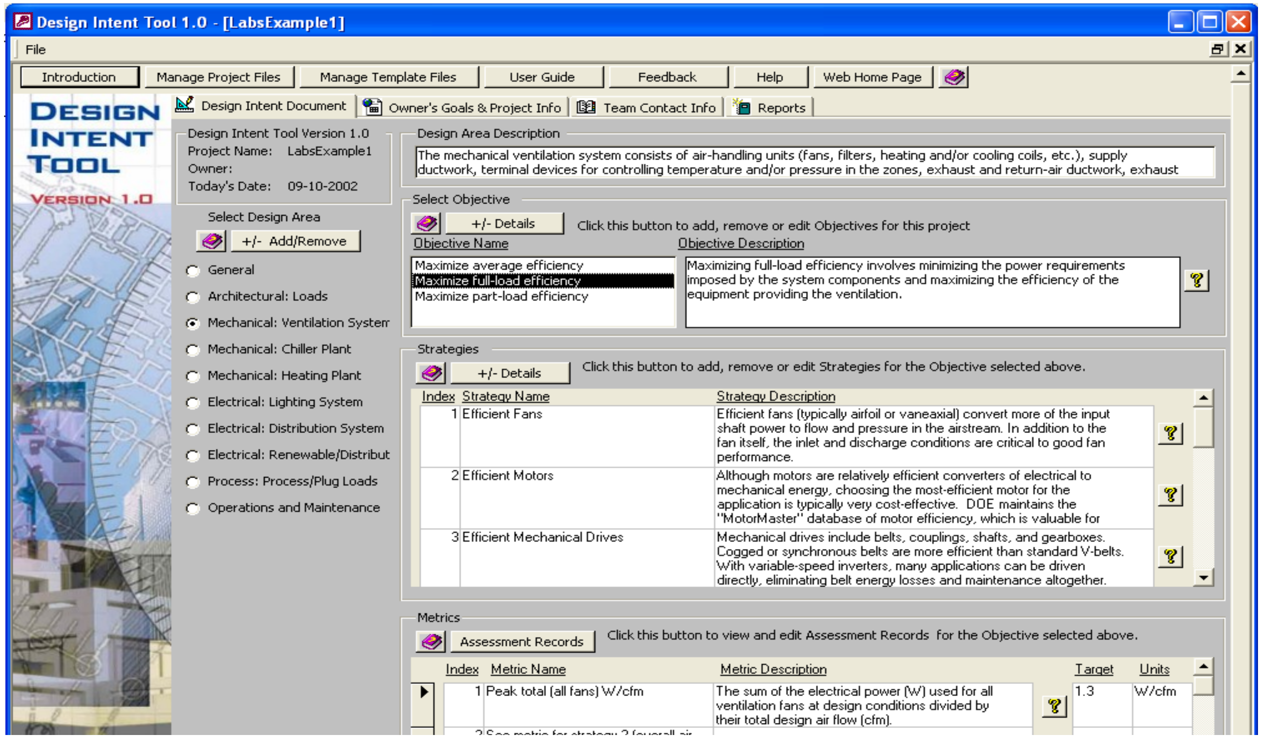
Process Manual

- **Action items for each stage of design process**
  - Links to appropriate tools and resources
- **Checklist of sustainable design strategies**
  - Portal to core information resources
  - Useful for design charrettes



Design Intent Tool

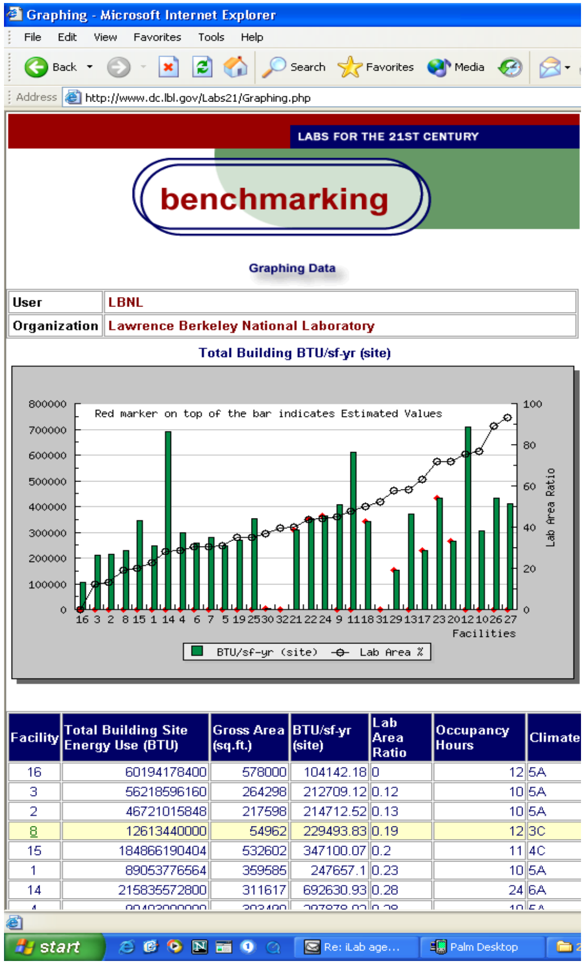
- **A database tool to document intended strategies and metrics during design**



Design process tools

Energy Benchmarking Tool

- National database of lab energy use data
- Web-based input and analysis
- About 70 facilities
- Building level data (e.g. Site BTU/sf)
- System level data (e.g. W/cfm)
- Why benchmark?
  - See where you stand
  - Set targets

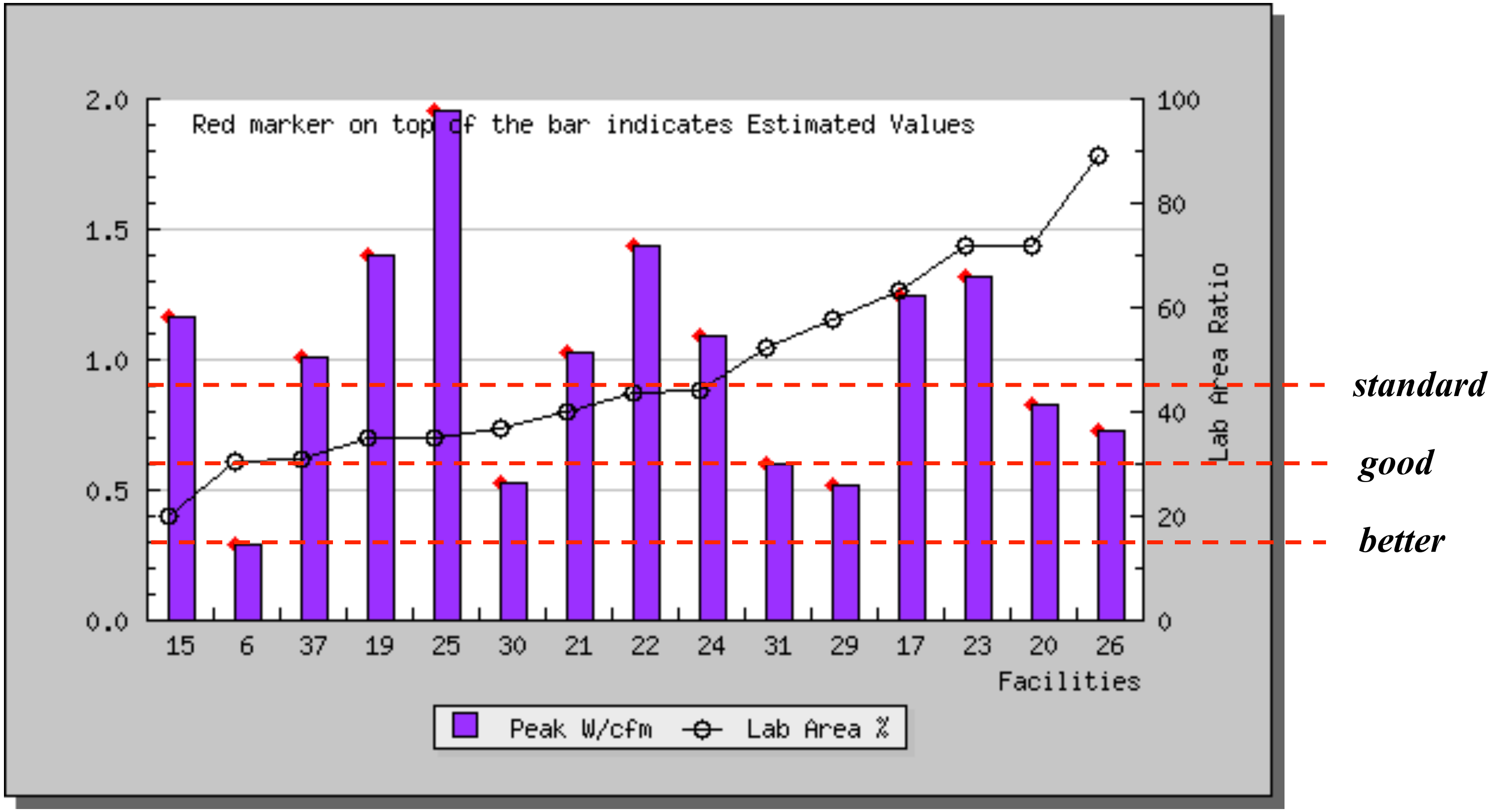


Facility	Total Building Site Energy Use (BTU)	Gross Area (sq.ft.)	BTU/sf-yr (site)	Lab Area Ratio	Occupancy Hours	Climate
16	60194178400	578000	104142.18	0	12	5A
3	56218596160	264298	212709.12	0.12	10	5A
2	46721015848	217598	214712.52	0.13	10	5A
8	12613440000	54962	229493.83	0.19	12	3C
15	184866190404	532602	347100.07	0.2	11	4C
1	89053776564	359585	247657.1	0.23	10	5A
14	215835572800	311617	692630.93	0.28	24	6A

Benchmarking Metrics

System	Energy Consumption	Energy Demand
Ventilation	kWh/sf-yr	Peak W/cfm Peak cfm/sf (lab) Avg cfm/peak cfm
Cooling	kWh/sf-yr	Peak W/sf Peak sf/ton kW/ton
Lighting	kWh/sf-yr	Peak W/sf
Process/Plug	kWh/sf-yr	Peak W/sf
Heating	BTU/sf-yr	Peak W/sf
Aggregate	kWh/sf-yr (total elec) BTU/sf-yr (site) BTU/sf-yr (source) Utility $/sf-yr	Peak W/sf Effectiveness (Ideal/ Actual)

Labs21 Benchmarking Tool – Vent. W/cfm



Standard, good, better benchmarks as defined in
"How-low Can You go: Low-Pressure Drop Laboratory Design"
by Dale Sartor and John Weale

Environmental Performance Criteria (EPC)

- **Rating system for evaluating laboratory design**
  - Builds on the LEED™ rating system
- **Adds Lab specific credits and prerequisites**
  - Health & Safety
  - Fumehood energy use
  - Plug loads
- **Leveraged volunteer efforts**
- **USGBC developing LEED for Labs based on EPC**

EPC & LEED

Indicates additions/modifications to LEED

Yes	?	No			
0	0	0	**Sustainable Sites**		16
Y			Prereq 1	**Erosion & Sedimentation Control**	Required
			Credit 1	**Site Selection**	1
			Credit 2	**Urban Redevelopment**	1
			Credit 3	**Brownfield Redevelopment**	1
			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
			Credit 4.3	**Alternative Transportation**, Alternative Fuel Refueling Stations	1
			Credit 4.4	**Alternative Transportation**, Parking Capacity	1
			Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space	1
			Credit 5.2	**Reduced Site Disturbance**, Development Footprint	1
			Credit 6.1	**Stormwater Management**, Rate or Quantity	1
			Credit 6.2	**Stormwater Management**, Treatment	1
			Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof	1
			Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof	1
			Credit 8	**Light Pollution Reduction**	1
			Credit 9.1	**Safety and Risk Management**, Air Effluent	1
			Credit 9.2	**Safety and Risk Management**, Water Effluent	1

Yes	?	No			
0	0	0	**Water Efficiency**		7
Y			Prereq 1	**Laboratory Equipment Water Use**	Required
			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
			Credit 2	**Innovative Wastewater Technologies**	1

How to Become Involved

- **Visit: www.labs21century.gov**
- **E-mail the Labs21 Network: labs21@erg.com**
- **Contact me:**

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Labs21:
Five Big Hits Towards Best Practice

September 11, 2006 Dale Sartor, P.E.

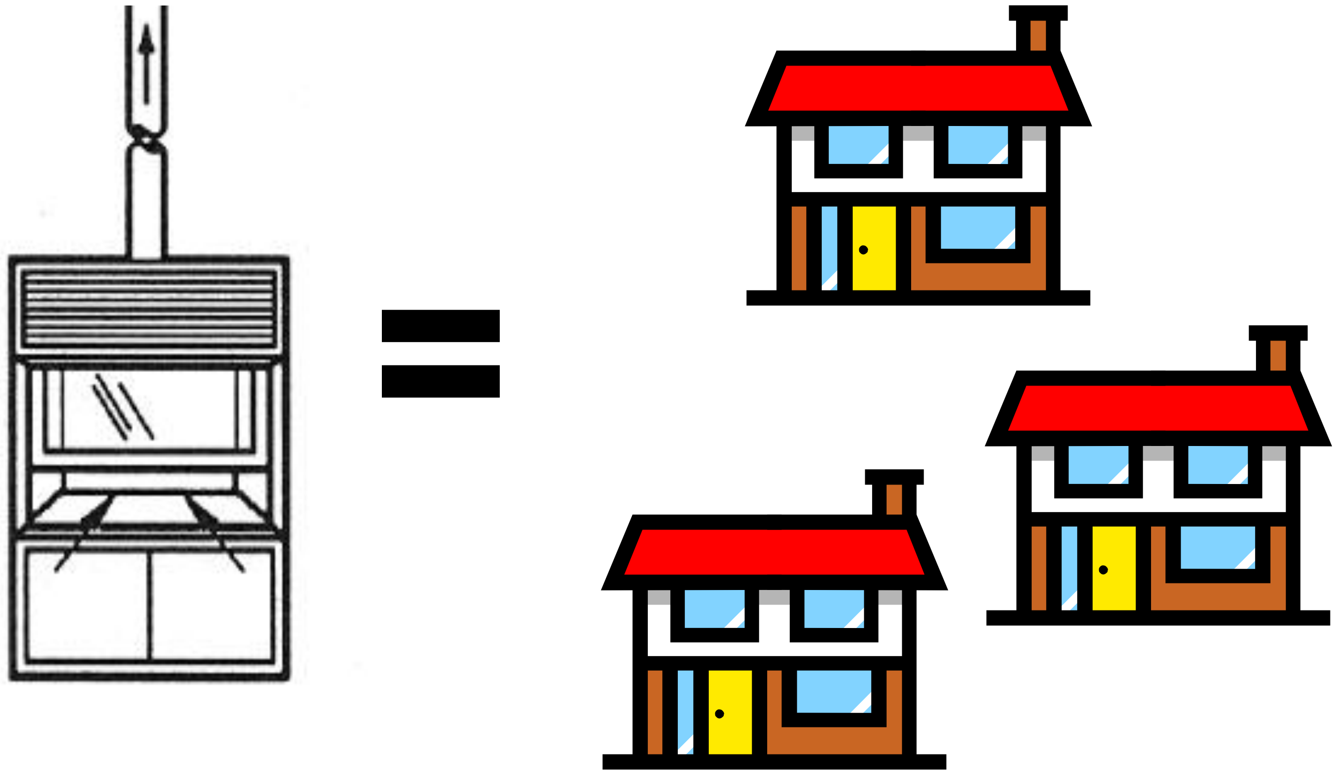
Lawrence Berkeley National Laboratory

More detail on specific best practices: Five BIG HITS

1. Tame the hoods
2. Scrutinize the air changes
3. Drop the pressure drop
4. Get real with plug loads
5. Just say no to re-heat

1. Tame the Hoods

Fume Hood Energy Consumption



Tame the Hoods

1. Reduce the number and size of hoods
2. Restrict the sash opening
3. Say no to Auxiliary Air hoods
4. Use Two “speed” occupied and un-occupied
5. Use variable air volume (VAV)
6. Consider high performance hoods

1. Reduce the number and size of hoods

- **Size distribution for ample capacity**
- **Install only hoods needed immediately**
- **Provide tees, valves, and pressure controls for easy additions/subtractions**
- **Encourage removal of underutilized hoods**
- **Consider hoods as a shared resource**

Is this hood intensity necessary?

2. Restrict sash openings

Sash stops | **Horizontal sashes** | **Combination**

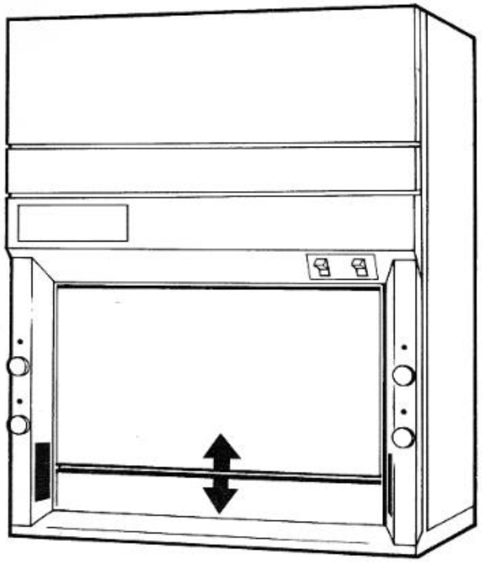


Figure 9. Hood with vertical-rising sash

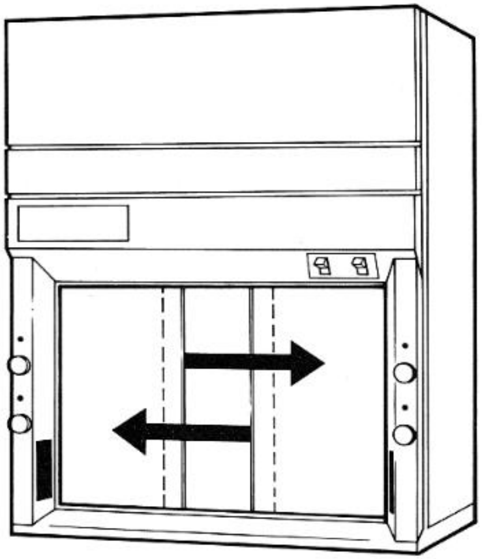


Figure 10. Hood with horizontal-sliding sashes

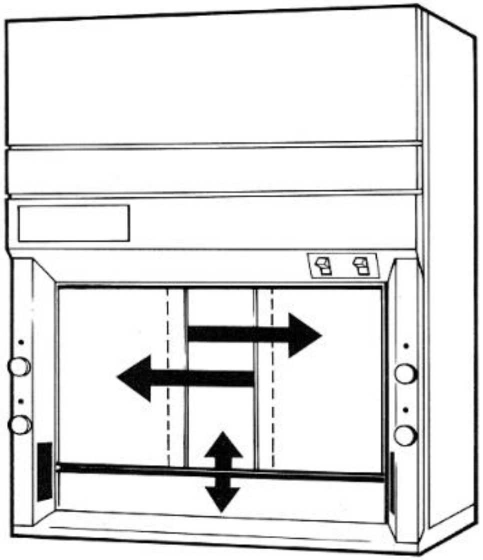


Figure 11. Hood with combination "A-style" sash

2. Restrict sash openings

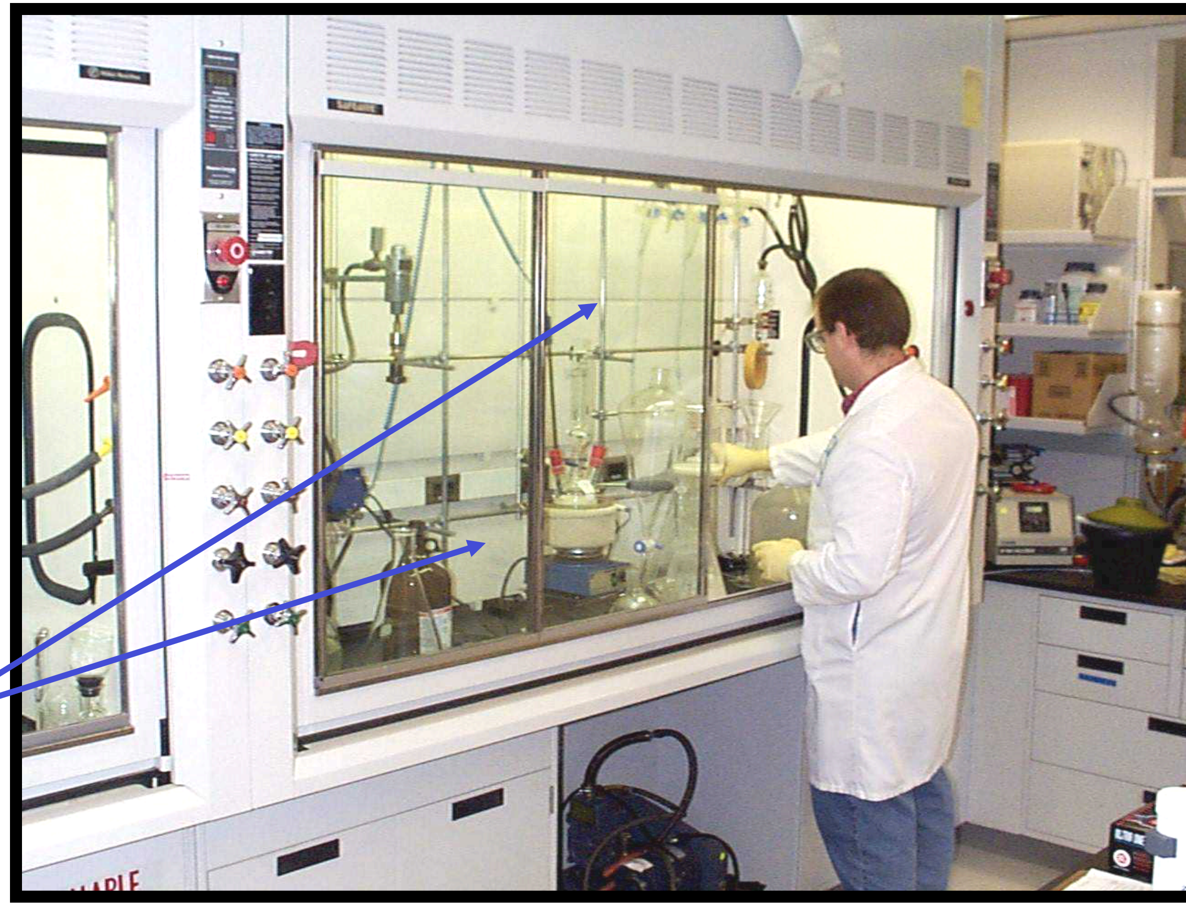
- **Vertical Sash Opening**
  - Most common sash
  - Good horizontal access
  - Energy use reduced with sash stop

Vertical Sash Stop

2. Restrict sash openings

- **Horizontal Sash**
  - Can be more energy efficient due to reduce airflow volume
  - May increase worker safety
  - Caution – sash panels can be removed; defeats safety

Sash Panels



3. Auxiliary air hoods

- **Auxiliary Air Hood**
  - Wastes energy
  - Reduces containment performance
  - Decreases worker comfort
  - Disrupts lab temperature and humidity
  - **Not Recommended**

4. Two “speed” occupied/un-occupied

Zone Occupancy Sensor Sash Sensor/Monitor

5. Variable air volume (VAV)

VAV:

…Combination of sophisticated monitoring sensors and controls

How Do They Operate?

…Communicate between hood and supply/exhaust systems

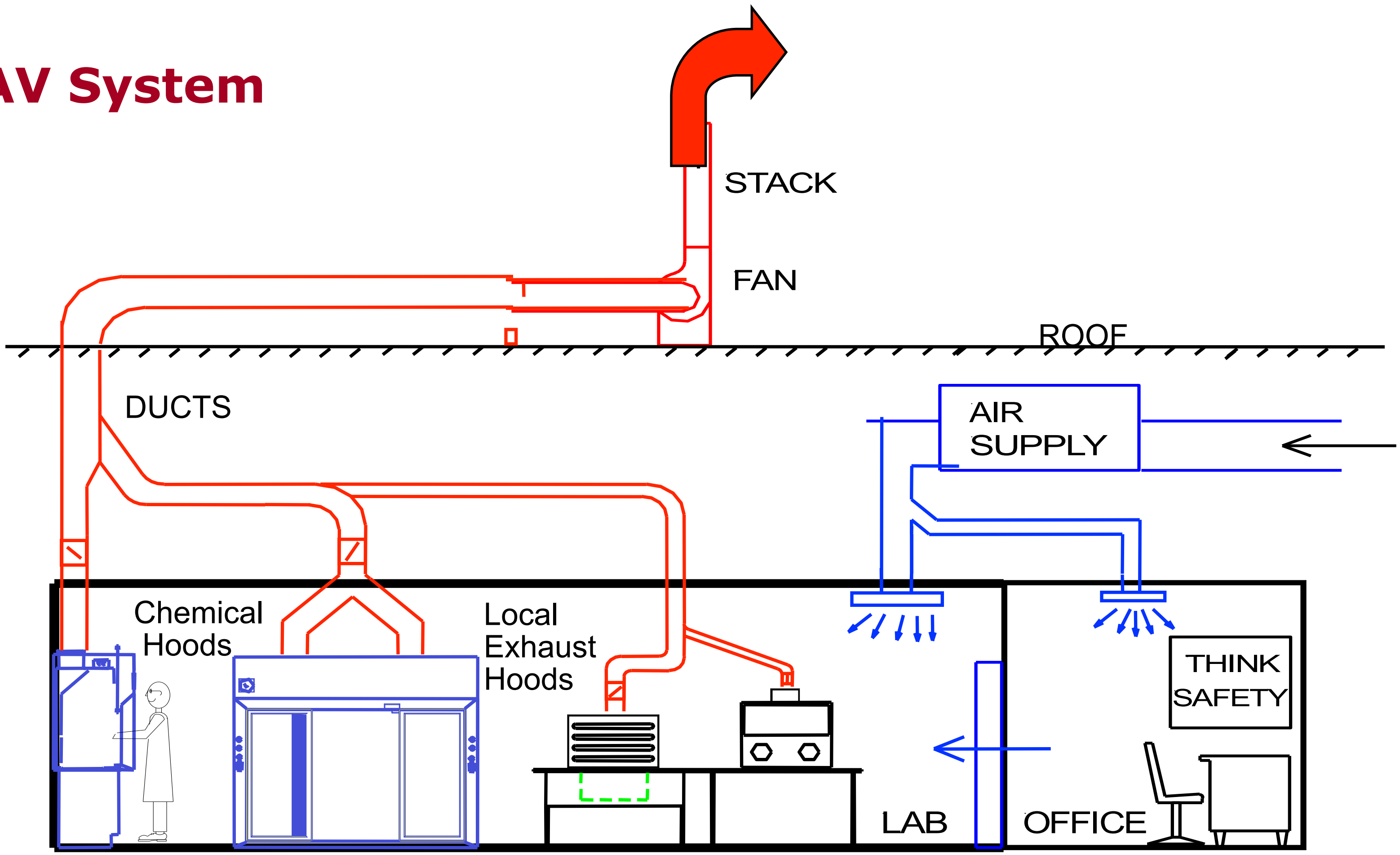
…Modulate supply/exhaust systems

…Maintain constant face velocity and room pressure relationships

TSI Controller

5. Variable air volume (VAV)

VAV System



VAV Drawbacks

Key Requirement

Diligent users must close sash to reduce air flow

Energy Savings

Reduced fan speed with closed sash

Typical Worst Case Sizing

Assume all sashes open 100%

Result

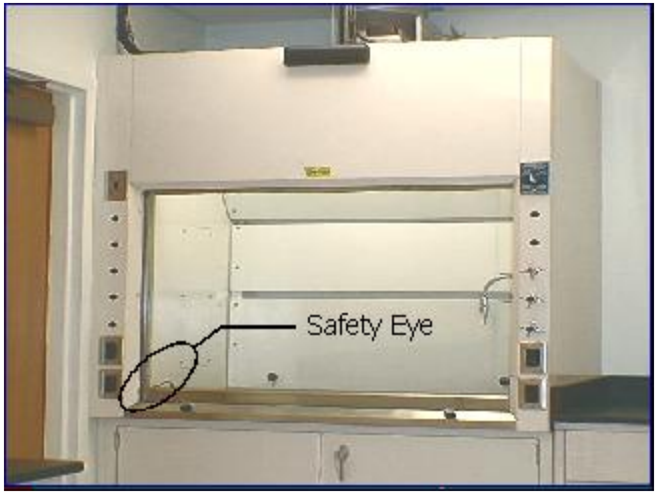
Oversized fans and central plants

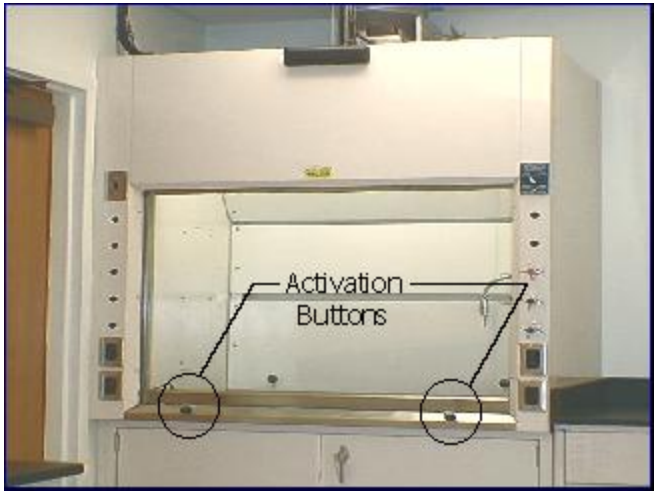
5. VAV sash management

- Training and education
- The stick
- The carrot
- Demand responsive sash management
- Automated sash management
  - occupied and unoccupied set points (reset velocity set point)
  - Auto sash closure system

5. VAV sash management

- **New-Tech Automatic Sash Positioning System**





6. High Performance Hoods

Does the Low Flow / Low Velocity Hood provide:

- Energy-efficient operation?
- Equivalent or Better Containment at Reduced Face Velocities and Flow Volumes?
- Improved performance for all users, even under misuse conditions?
- More Robust and Less Susceptible to External Factors?
- Better Monitoring and Flow Control?

If so… = High Performance Hood

6. High Performance Hoods

- **Improved Performance Through Better Design…**
  - Aerodynamic Entry
  - Directed Air Supply
  - Perforated or Slotted Rear Baffle
  - Airfoil Sill and Sash Handle
  - Integrated Monitors
  - Interior Dimensions
- **First Generation: 20 to 40% savings**
- **Second Generation: 40 to 75% savings**

6. High Performance Hoods

- **Current fabricators…**
  - Lab Crafters
  - Labconco
  - Fisher Hamilton
  - Kewaunee Scientific
  - Laboratory Equipment Manufacturers
  - Esco Global
  - Others

6. High Performance Hoods

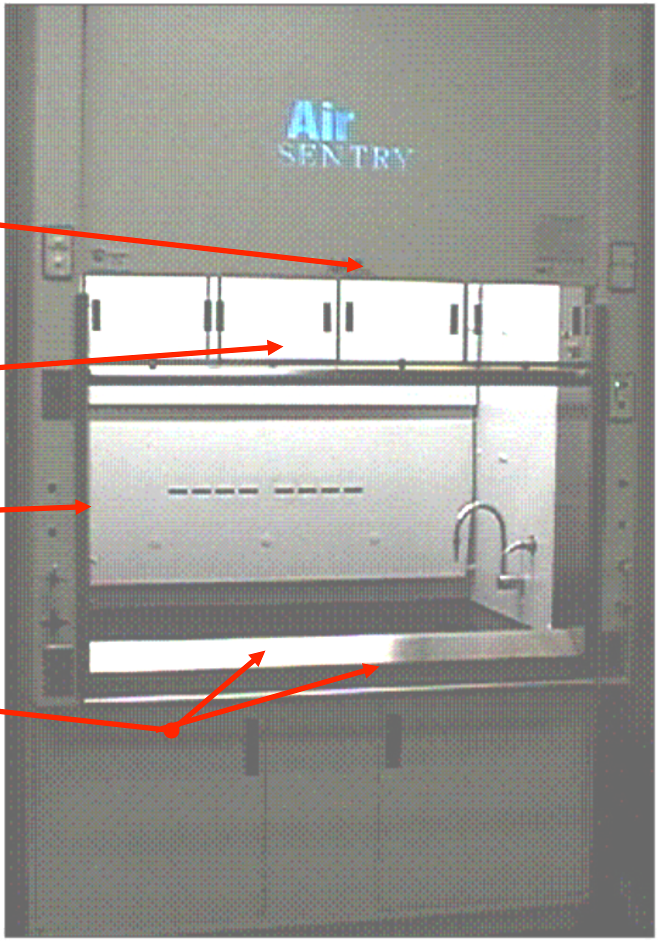
Lab Crafters Air Sentry HPFH

Upper chamber Turning Vane

Aerodynamic Sash Frame

Side Post Airfoils

Multi-Slot Front Airfoil



6. High Performance Hoods

Labconco XStream Hood

Modified Aerodynamic Sash Pull

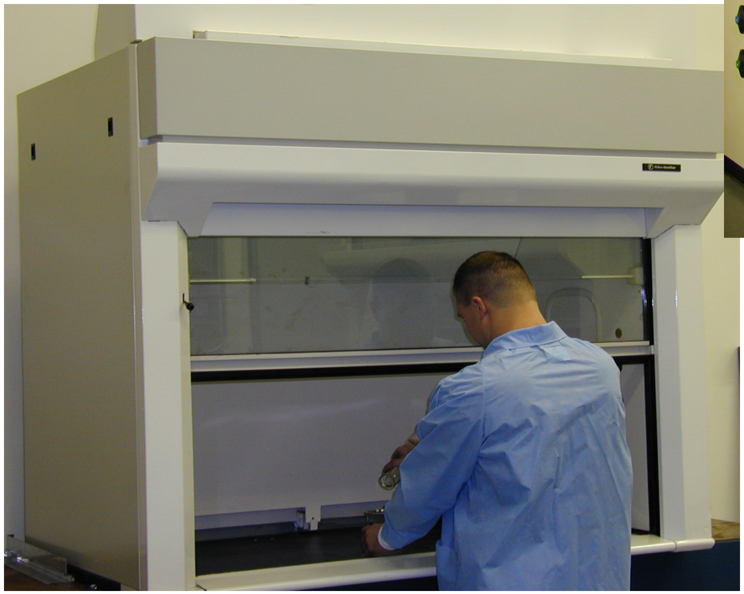
Modified Baffle and Slots

Aerodynamic Airfoil

6. High Performance Hoods

Fisher Hamilton PIONEER

- Automatic sash closer
- Directed supply flow @ full open sash
- Flush Airfoil Sill



6. High Performance Hoods

Berkeley Hood by LBNL

- Push/Pull Air Divider Technique
- Perimeter Air Supply
- Perforated Rear Baffle
- Slot Exhaust & Optimized Upper Chamber
- Designed to minimize escape by reducing reverse flow
- Reduces air flow 50-75%

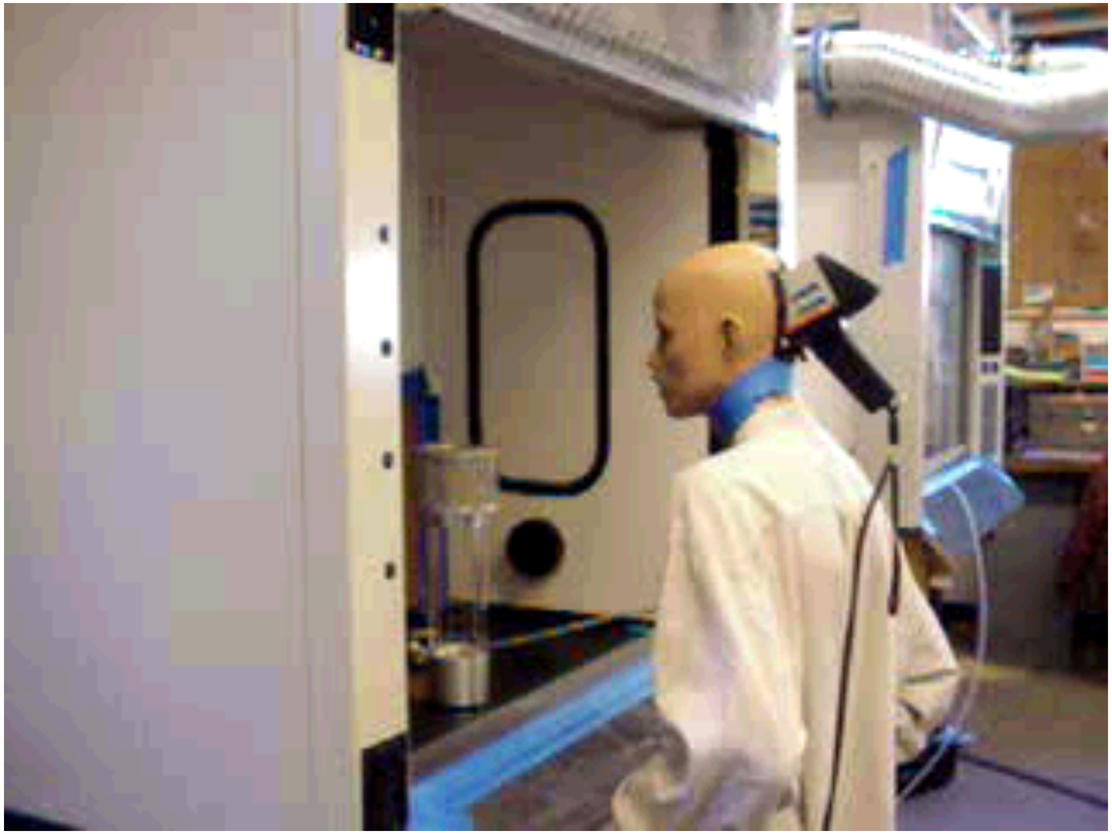
Laboratory Fume Hood Testing for Safety

Smoke in Supply Plenums…

Exhaust:
40% "normal" flow

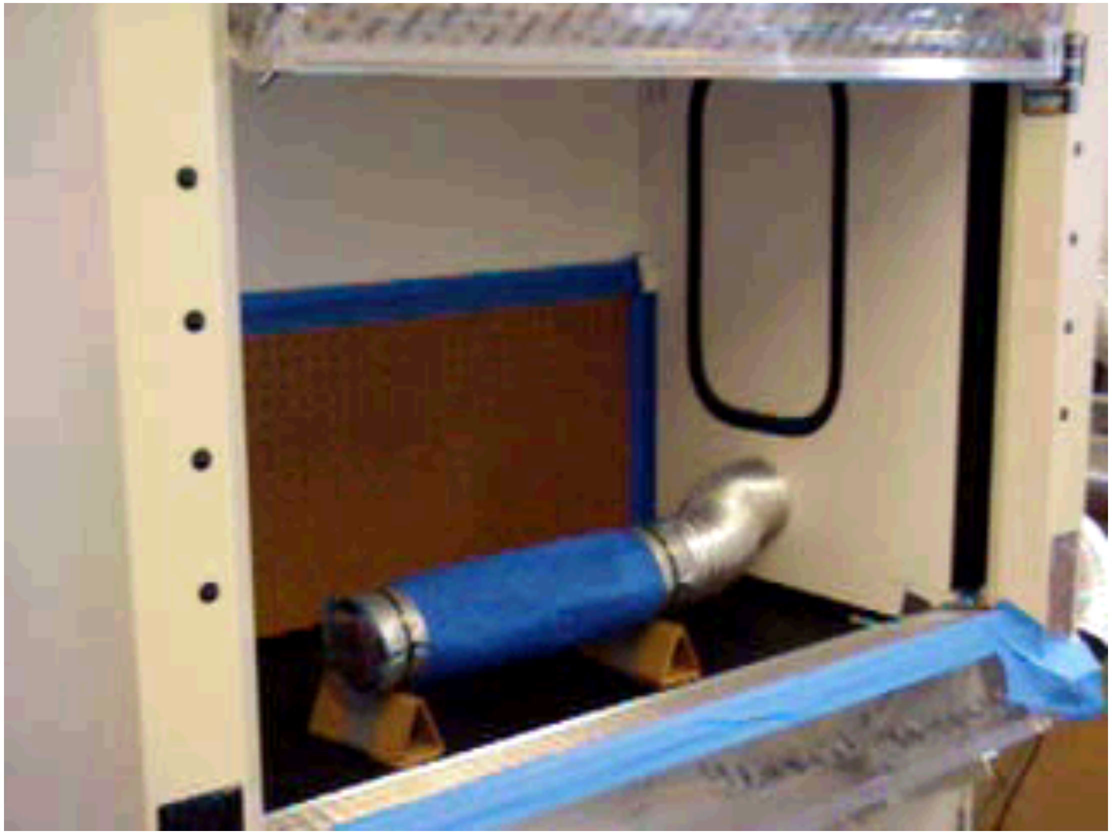
Ejector:
8L/min.

Breathing Zone:
18 inches



Laboratory Fume Hood Testing for Safety

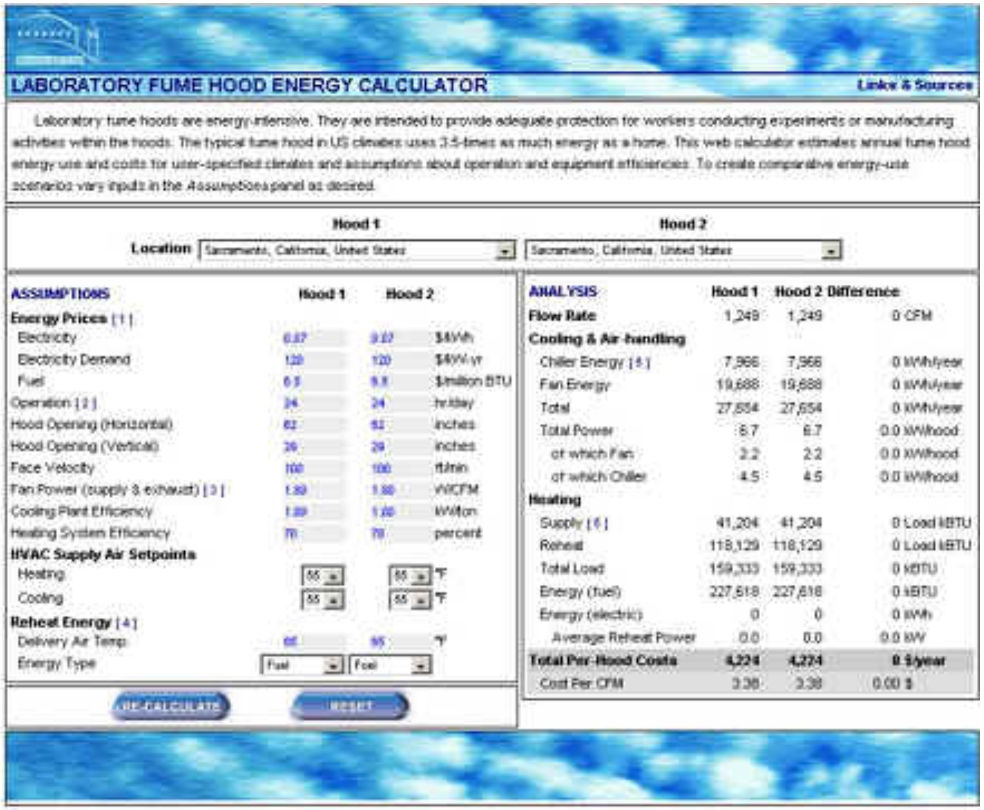
Smoke containment...



Smoke visualization test at 30% “normal” flow

Resource…

Fume Hood Energy Calculator:



Calculator web site:

http://fumehoodcalculator.lbl.gov/

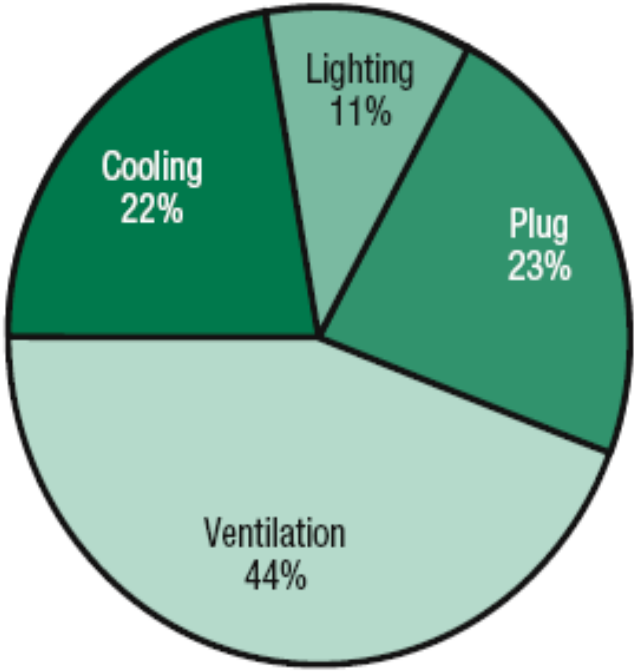
The calculator can be used to test the energy and cost impacts of improving component efficiencies (e.g. fans or space conditioning equipment), modifying face velocities, and varying energy prices. Supply air set points can be varied, as can the type of reheat energy. Several hundred weather locations around the world are available. The calculator allows for an instantaneous comparison of two scenarios.

2. Scrutinize the Air Changes

- **Don't assume air changes are driven by thermal loads**
- **What do you use as minimum ACH?**
  - Why? Why? Why?
- **When is ten or more air changes safe and six air changes (or less) not?**
- **Very large peak and operating cost impact**

Ventilation Energy in Laboratories

– Up to 50% of electrical energy use
– Small reductions have large impact
– Affects cost to build and maintain facility



Annual electricity use in Louis Stokes Laboratory, National Institutes of Health , Bethesda, MD

Maximize Effectiveness; Minimize Energy Use

Optimizing Ventilation

Why ventilation?

- Worker Safety
- Space conditioning

What is "optimizing"?

- Air Change Rate
- Air Dilution
- Air Circulation

An optimized laboratory design both safely handles the "worst" emergency and efficiently manages "routine" incidents and normal conditions

Modeling and Simulation

Modeling Methods…

- **Tracer Gas Evaluations**
- **Neutrally-buoyant helium bubble evaluations**
- **Computational Fluid Dynamics (CFD)**

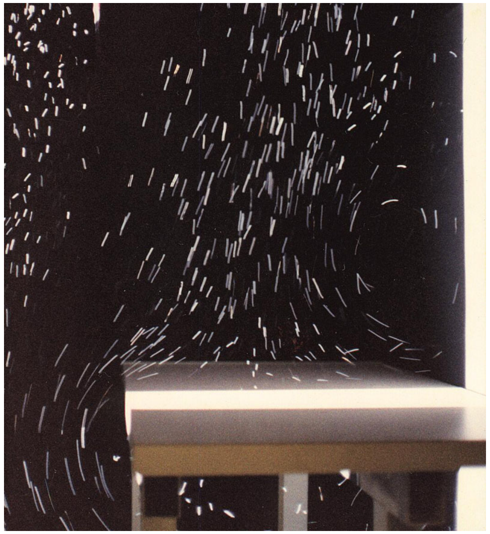
Evaluate…

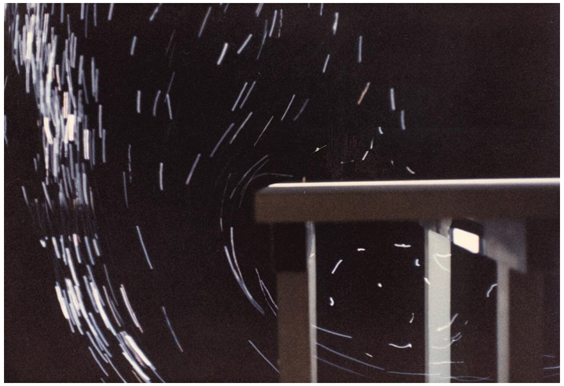
- **Containment**
- **Ventilation effectiveness**

Modeling and Simulation

- **Tracer Gas Evaluations**
  - Provides "clearing time" with tracer gas rate-of-decay
  - Confirms actual air change rate effectiveness
  - ASHRAE provides guidelines

- **Neutrally-buoyant helium bubble evaluations**
  - Study and adjust airflow patterns
  - Optimize register and diffuser placement
  - Safe and simple operation

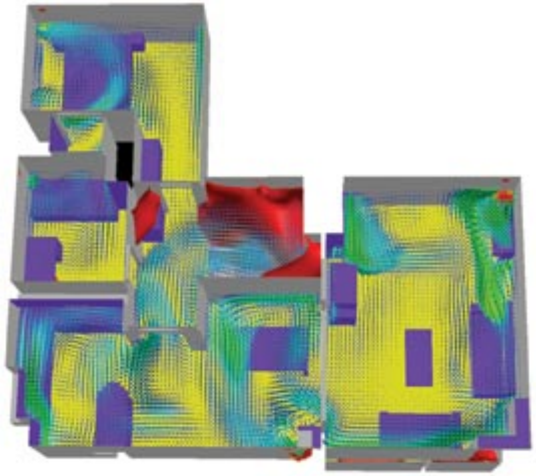




❖ **Considerations...**
  - Requires full-scale model, or existing lab

Modeling and Simulation

- **Computational Fluid Dynamics (CFD)**
  - Estimate residence time of hazard
  - Develop "answers" to spill scenarios
  - Evaluate placement of major design-elements: hoods, benches, registers
  - Examine numerous "what-if" scenarios
  - Avoid dead or "lazy" air or areas of air recirculation

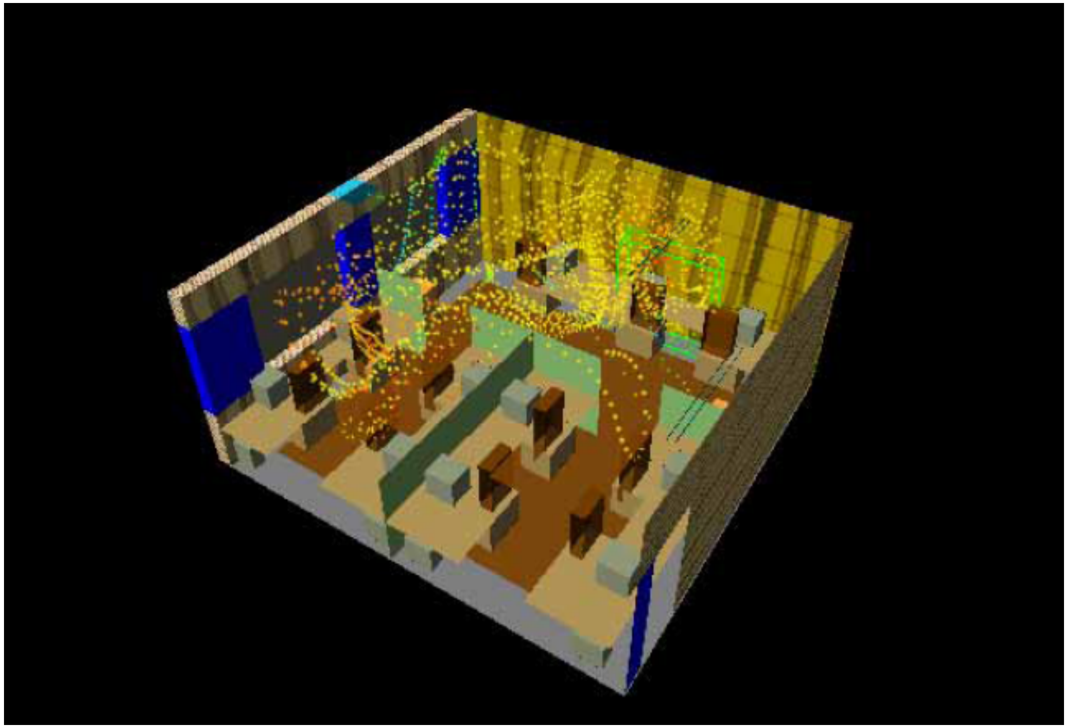


CFD Model courtesy CD-adapco

- **Considerations...**
  - Use experienced modeling company

Modeling and Simulation

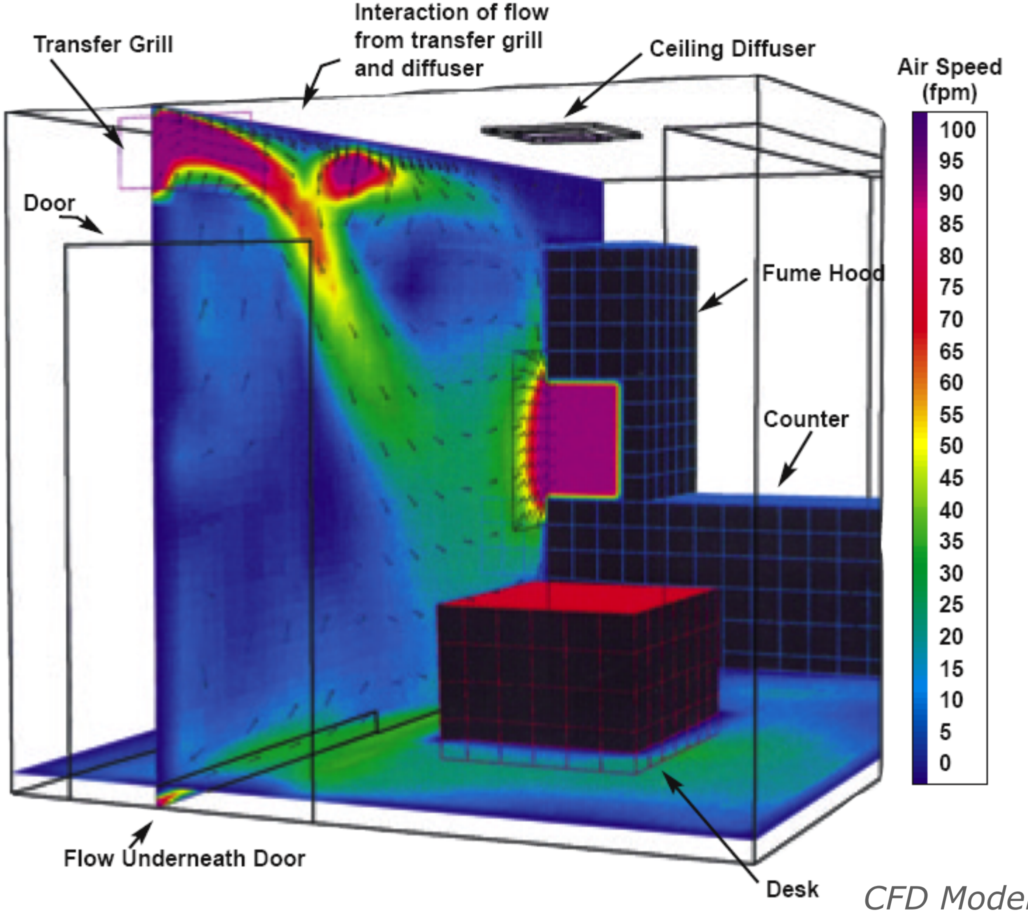
CFD Three-dimensional supply and exhaust airflow review



CFD Modeling courtesy Flow Sciences, Inc.

Modeling and Simulation

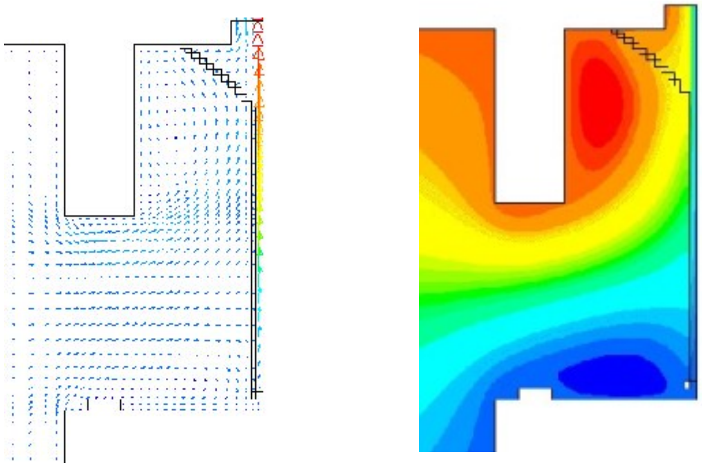
CFD two-plane supply and exhaust airflow review



CFD Modeling courtesy RWDI, Inc.

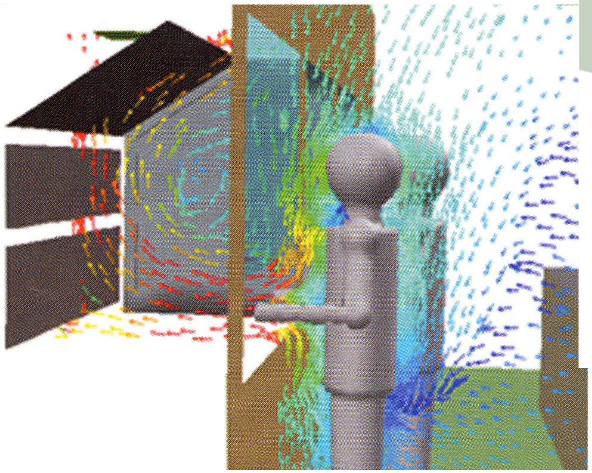
Modeling and Simulation

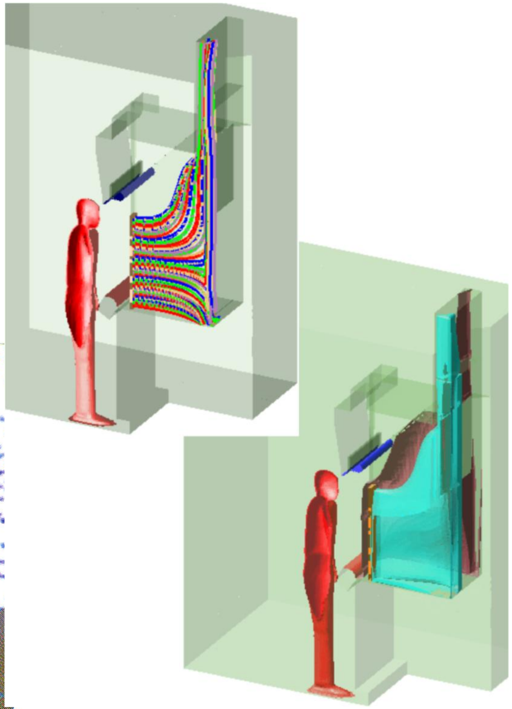
CFD Fume Hood Models…



Two-dimensional CFD

Three-dimensional CFD

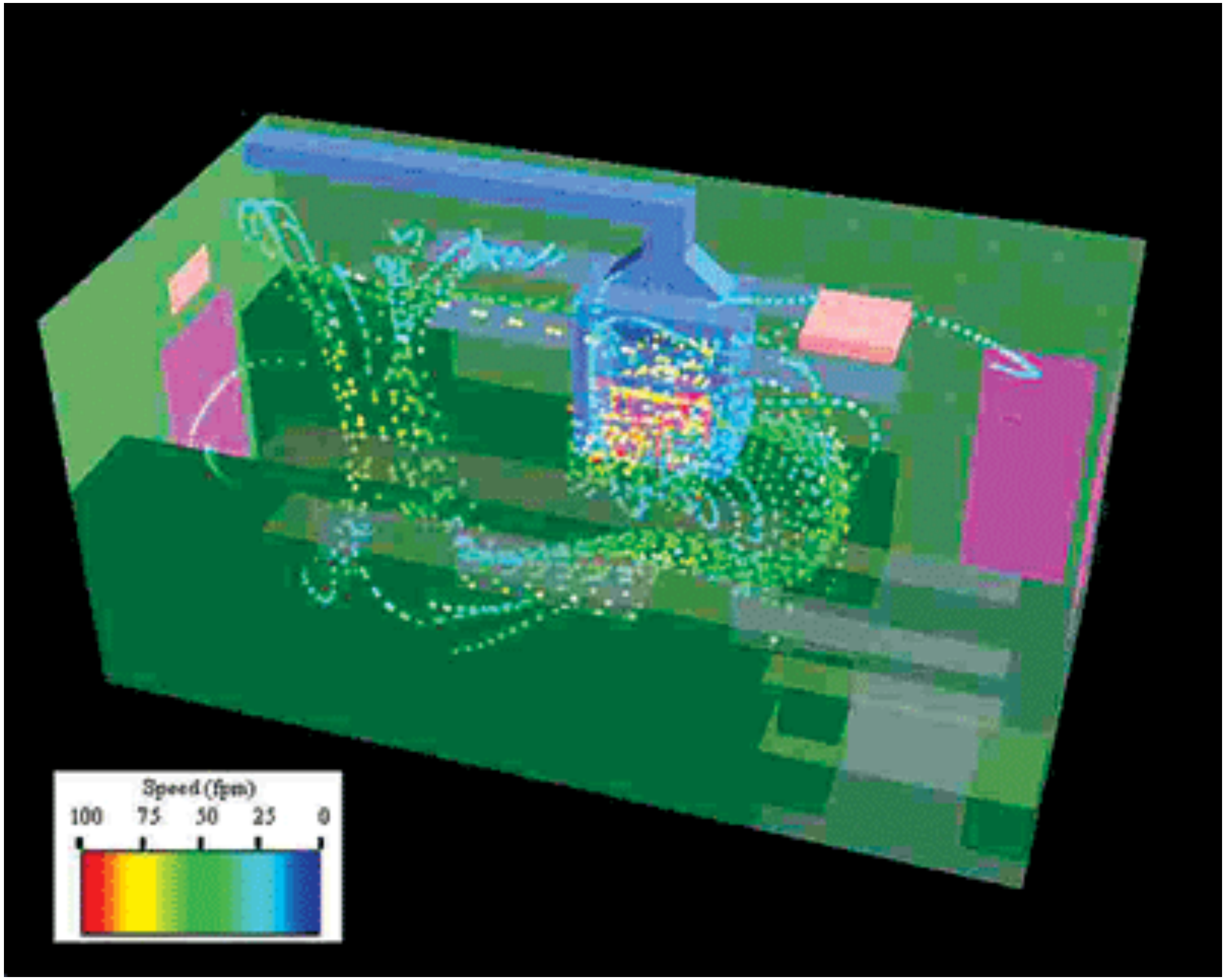




Modeling and Simulation

CFD Lab Model

Analysis of NIH lab…

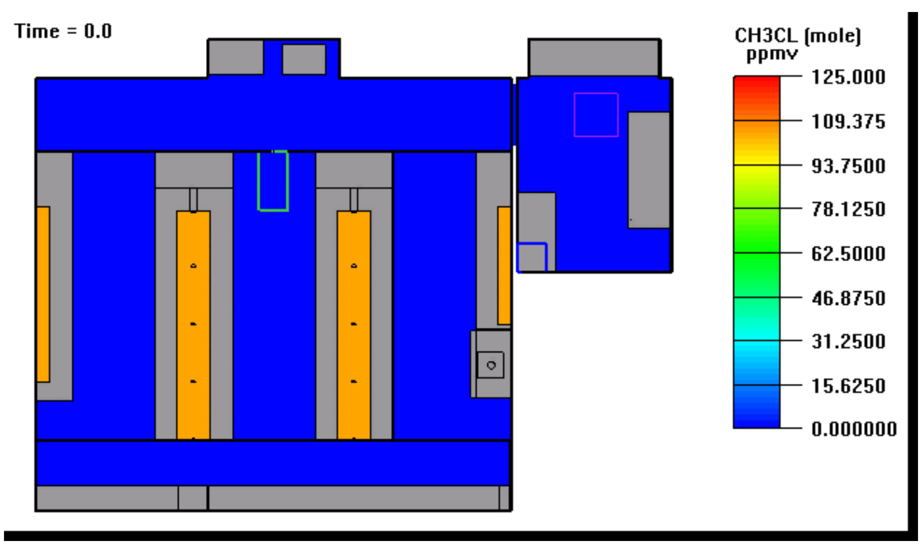


CFD Modeling courtesy Flomerics

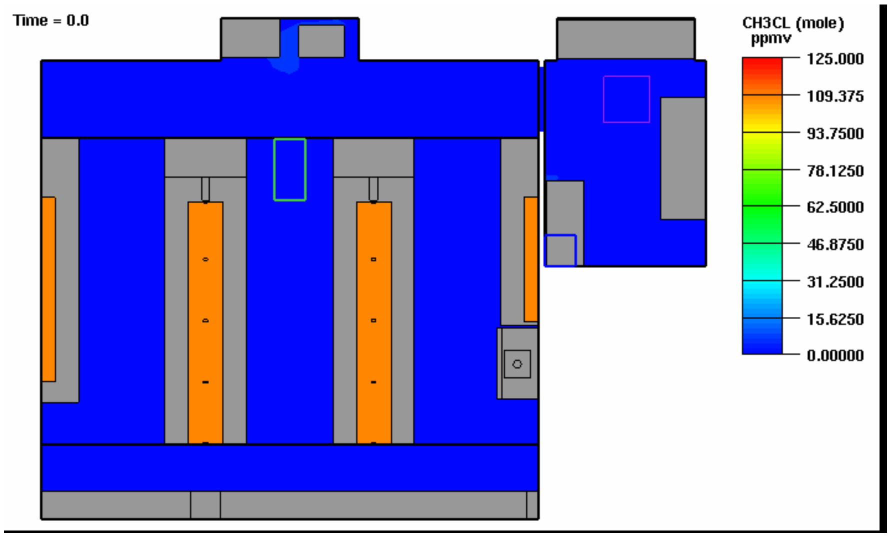
Modeling and Simulation

CFD model of pharmaceutical lab

12 ACH



8 ACH



CFD Modeling courtesy Fluent

- 1-liter liquid methyl chloride spill in isolation room
- 9 sq.ft. spill area
- Vaporization occurs over 600 seconds at constant rate

2. Scrutinize the Air Changes - Conclusions

- **Ventilation effectiveness in more dependent on lab and HVAC design than air change rates (ACR)**
- **High ACR can have a negative impact on containment devices**
- **Consider:**
  - **cfm/sqft rather than ACR**
  - **Panic switch concept**
  - **Cascading air from clean to dirty**
  - **Setback ACR when lab is unoccupied**
  - **Demand controlled ventilation (based on monitoring of hazards and odors)**

3. Drop the Pressure Drop

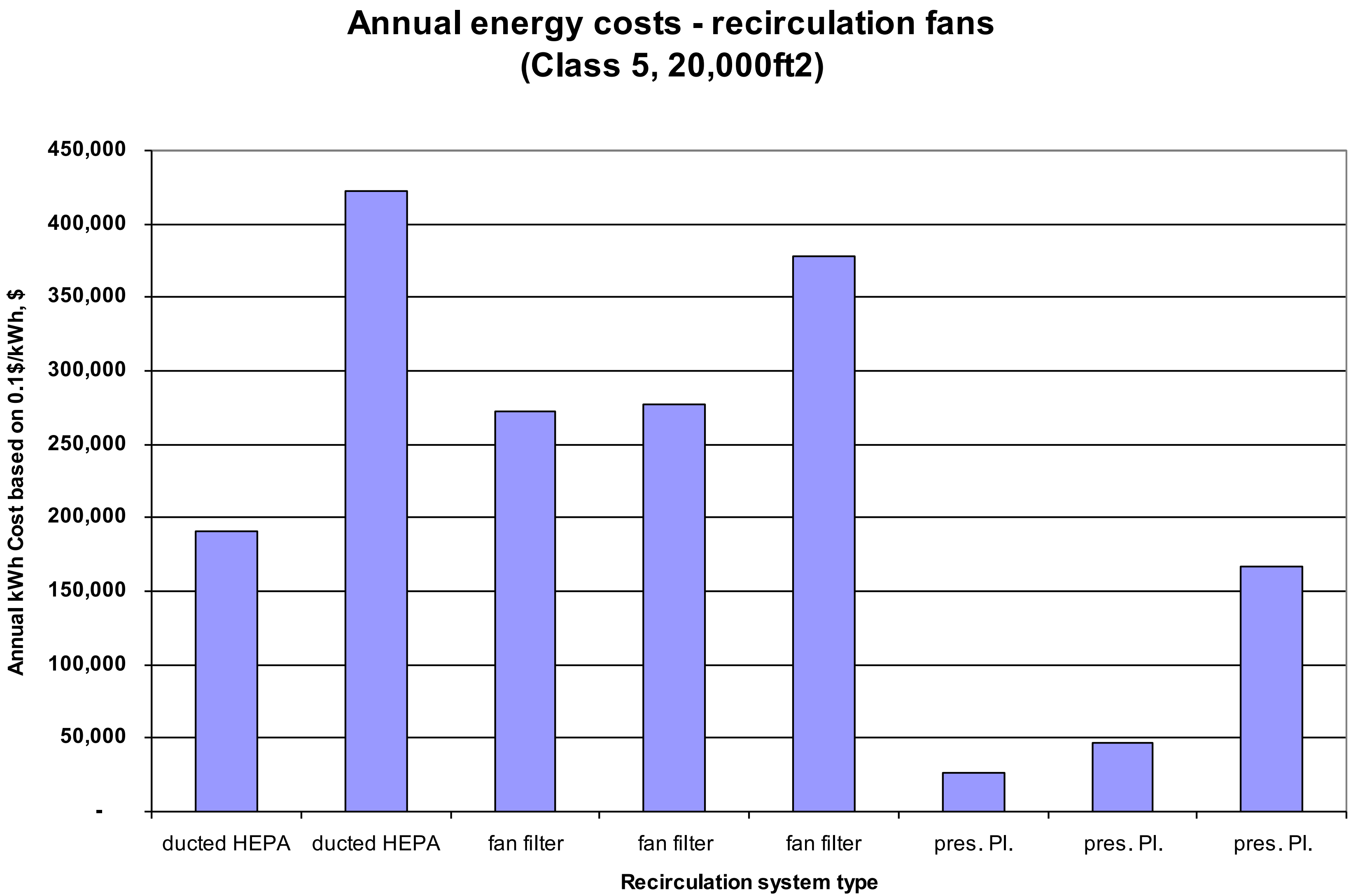
- Up to one half HVAC energy goes to fans
- How low can you go

Low Pressure-Drop Design Guidelines

Component	Standard	Good	Better
Air handler face velocity	500	400	300
Air Handler	2.5 in. w.g.	1.5 in. w.g.	0.75 in.w.g.
Heat Recovery Device	1.00 in. w.g.	0.60 in. w.g.	0.35 in. w.g.
VAV Control Devices	Constant Volume, N/A	Flow Measurement Devices, 0.60 - 0.30 in. w.g.	Pressure Differential Measurement and Control, 0.10 in. w.g.
Zone Temperature Control Coils	0.5 in. w.g.	0.30 in. w.g.	0.05 in. w.g.
Total Supply and Return Ductwork	4.0 in. w.g.	2.25 in. w.g.	1.2 in. w.g.
Exhaust Stack CFM and	0.7" w.g. full design flow through entire exhaust system, Constant Volume	0.7" w.g. full design flow through fan and stack only, VAV System with bypass	0.75" w.g. averaging half the design flow, VAV System with multiple stacks
Noise Control (Silencers)	1.0" w.g.	0.25" w.g.	0.0" w.g.
Total	9.7" w.g.	6.2" w.g.	3.2" w.g.
Approximate W / CFM	1.8	1.2	0.6

Source: J. Weale, P. Rumsey, D. Sartor, L. E. Lock, "Laboratory Low-Pressure Drop Design," ASHRAE Journal, August 2002.

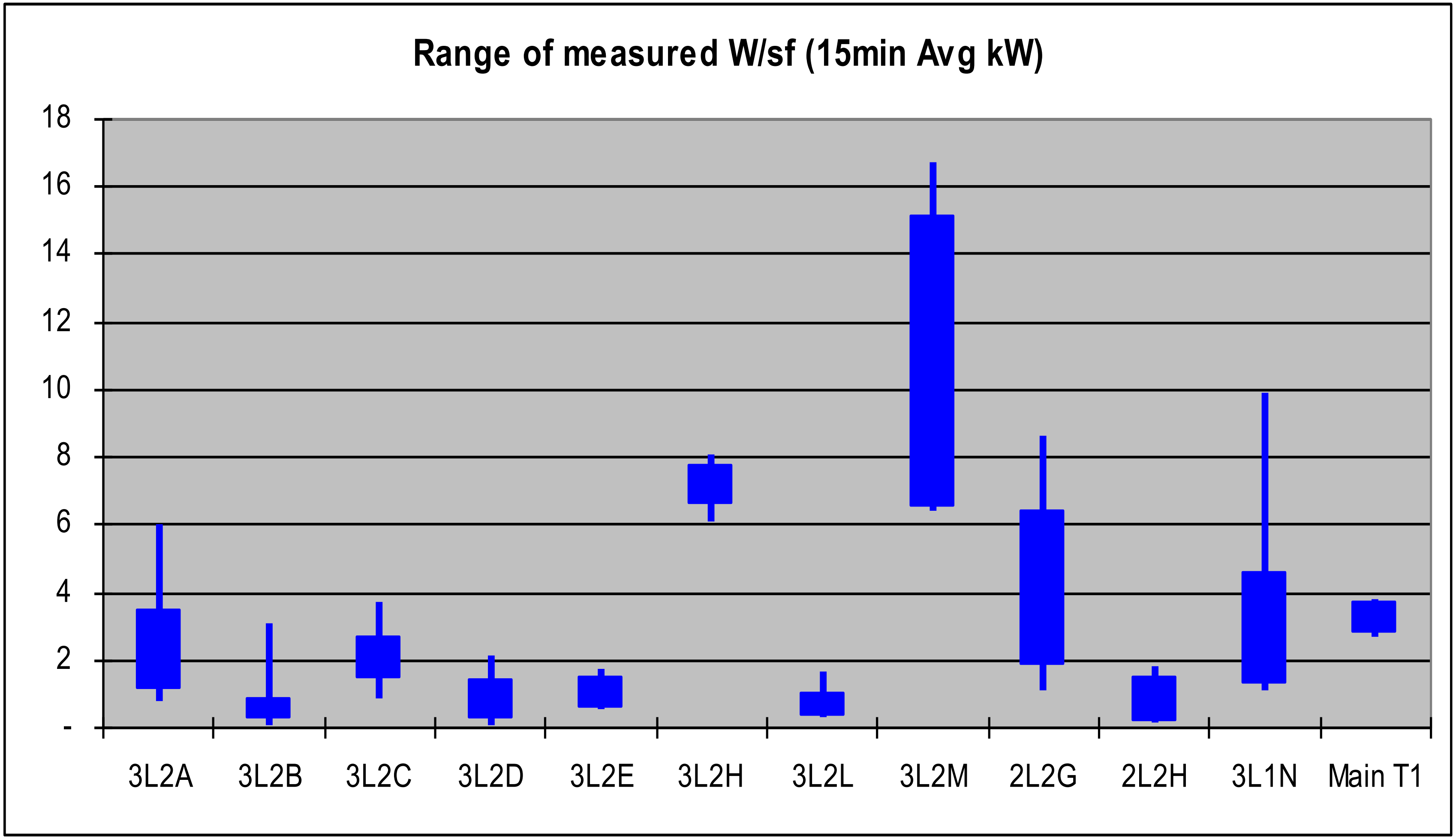
Annual Energy Cost for Cleanroom Recirculation Fans



4. Get Real with Plug Loads

- **Save capital cost and operating cost**
- **Measure actual loads in similar labs**
- **Design for high part- load efficiency**
  - Modular design approaches
- **Plug load diversity in labs increases reheat**

Measured Plug Loads



UC Davis – 16-58 W/sf design

5. Just Say No to Reheat

- **Reheat results in energy waste in labs**
  - High-load areas require lower supply air temperature, so reheat occurs in other spaces
- **Simultaneous heating and cooling more problematic in labs where variations of internal loads can be enormous**
- **A single zone requiring cooling can create artificial heating and cooling loads throughout the building**
- **Some possible solutions:**
  - Put cooling coils or cooling fan coils in each zone
  - Use a dual duct system with cool duct and neutral (70 deg. +/-) duct

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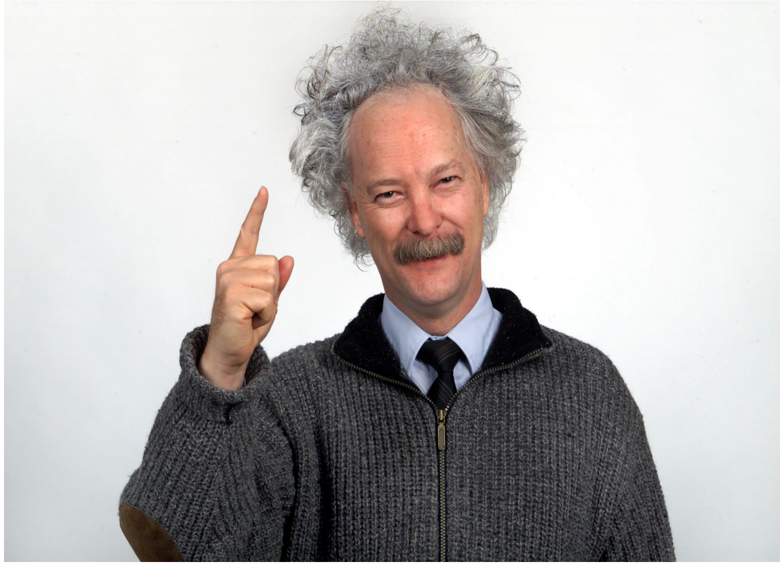

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